Final Report for FA2386-10-1-4111 AOARD Grant 104111

Research Title: Passivation of InAs and GaSb with novel high κ dielectrics

Date: April 21, 2011

Professor Minghwei HONG
Department of Materials Science and Engineering, National Tsing Hua University
Hsinchu, Taiwan, Republic of China
Phone: 886-3-574-2283; FAX: 886-3-572-2366; mhong@mx.nthu.edu.tw

Professor J. Raynien KWO
Center of Condensed Matter Sciences, National Taiwan University
Taipei, Taiwan, Republic of China
Phone: 886-2-3366-5200; FAX: 886-2-2365-5404; raynien@ntu.edu.tw

Period of Performance: 03/May/2010 – 02/May/2011

InAs MOS devices with MBE-grown Gd_2O_3 passivation

InGaAs with high κ dielectrics is now viable for complementary metal-oxide-semiconductor (CMOS) devices beyond the 15 nm node technology. Recently, intensive research activities for achieving low interface density of states and excellent performance of inversion-channel MOS field-effect transistors[1-4] have been put on $In_xGa_{1-x}As$ (x=0, 0.2, 0.53, 0.75), however, with less efforts on InAs.[5] Note that the latter has very high bulk electron mobility (~30000 $cm^2V^{-1}s^{-1}$) and saturation velocity (~8×10^7 cm/s). In this work, chemical and electronic characteristics on Al_2O_3/Gd_2O_3/InAs interface were studied using x-ray photoelectron spectroscopy (XPS). Electrical properties for MOSCAPs and depletion-mode MOSFETs were also studied.

The samples were grown by solid-source molecular beam epitaxy (MBE) on semi-insulating (100) GaAs substrate. The structure, following the growth sequence, consisted of a 200 nm-thick GaAs buffer layer, a 10 nm-thick AlAs transition layer, a 0.2 μm AlSb/ 1.3 μm $Al_{0.7}Ga_{0.3}Sb$ composite buffer layer, a 20 nm AlSb barrier, and a 5 nm-thick InAs channel layer. A tellurium δ-doping was placed at 25 nm below the InAs channel layer. The sample was then passivated by

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
27 APR 2011	**Final**	**29-04-2011 to 28-04-2011**

4. TITLE AND SUBTITLE
Passivation of InAs and GaSb with High κ Dielectrics - Growth, Structural, Chemical and Electrical Characterization

5a. CONTRACT NUMBER
FA23861014111

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Minghwei Hong

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Tsing Hua University,101, Section 2, Kuang Fu Rd,Hsinchu 30055, Taiwan,NA,NA,NA

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AOARD, UNIT 45002, APO, AP, 96338-5002

10. SPONSOR/MONITOR'S ACRONYM(S)
AOARD

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AOARD-104111

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This is the final report of a project in which chemical and electronic characteristics on Al2O3/Gd2O3/InAs interfaces were studied using x-ray photoelectron spectroscopy.

15. SUBJECT TERMS
Indium Arsenide, Gallium Antimonide, ALD-MBE Integration

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

arsenic at low temperature and ex-situ transferred for deposition of high κ's. An additional InAs layer (~2 nm) was freshly grown before the subsequent Gd_2O_3 (3 mono-layers) was e-beam evaporated to passivated the InAs surface; finally, followed by the atomic layer deposited Al_2O_3.

Energy-band offsets of the ALD-Al_2O_3/Gd_2O_3/InAs were obtained using XPS. The valence-band offset ~3.92 eV was determined by measuring the core level to valence band maximum binding energy difference from the XPS spectra, as shown in Fig. 1. With energy-band gaps of 0.35 and 6.7 eV for InAs and Al_2O_3, the important parameter for MOS devices, conduction-band offset ~2.43 eV, were determined.[6] The sample was annealed in N_2-ambient at 300°C for 60 seconds before the process.

Gate-first process was used to fabricate the ring-gate device. Gate metal, Ti/Au, was first formed by a lift-off process. The ohmic metal was subsequently formed by gate oxide wet-etching, metal deposition and lift-off. The cross-section and top view of the device is shown in Fig. 2. MOS diodes fabricated via the same process exhibited C-V curves with minor dispersion, as shown in Fig. 3. A 12μm-gate-length device demonstrates a saturation drain current ($I_{d\text{-}sat}$) of 45μA/μm (at V_g=2V and V_d=2V), and a transconductance of 18μS/μm (at V_d=2V).

References

[1] T. D. Lin *et al.*, APL **93**, 033516 (2008)

[2] Y. Xuan *et al.*, IEEE Electron Device Lett. **29**,294 (2008)

[3] D. Lin *et al.*,Tech. Dig. – IEDM **2009**, 327

[4] C. A. Lin *et al.*, APL **98**, 062108 (2011)

[5] N. Li *et al.*, APL **92**, 143507 (2008)

[6] M. L. Huang *et al.*, APL **94**, 052106 (2009)

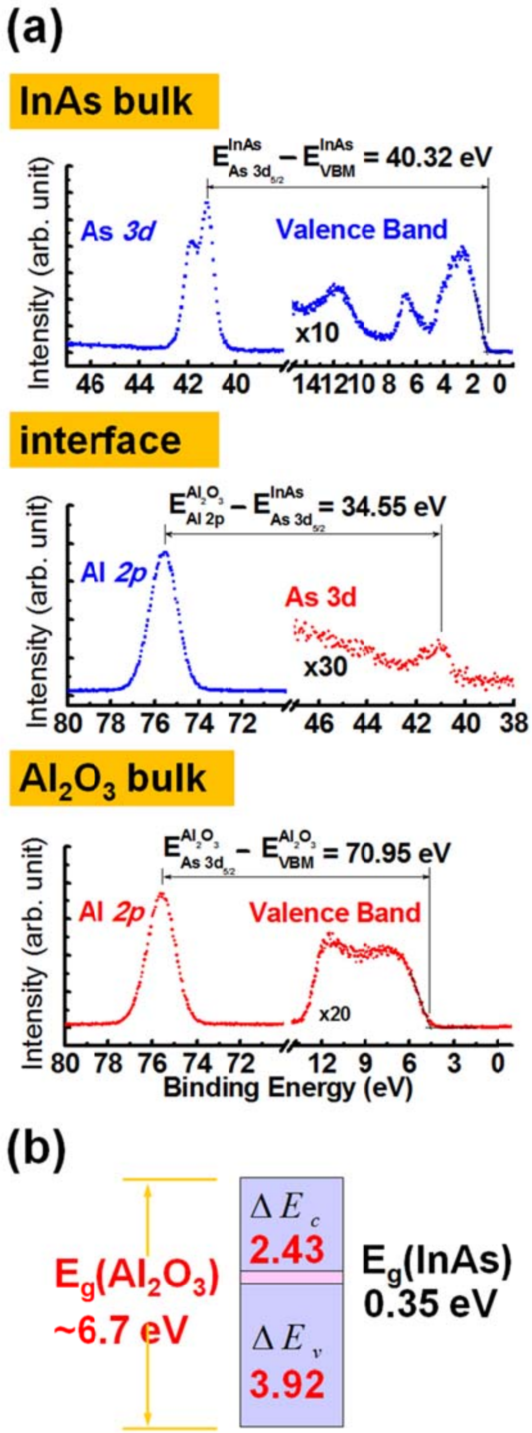

Fig. 1 (a) XPS spectra of As 3*d* CL and valence band of InAs film, Al 2*p* and As 3*d* CLs at ALD-Al2O3/Gd_2O_3/InAs interface, and Al 2*p* CL and valence band of Al2O3 film. (b) Energy-band parameters

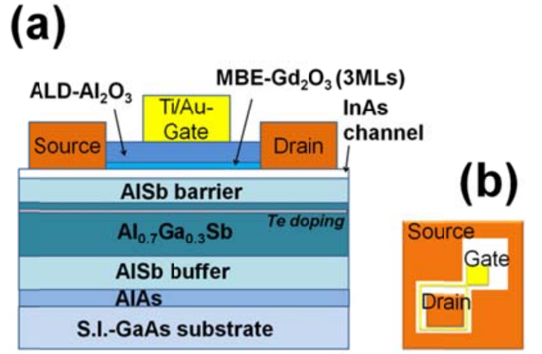

Fig. 2 (a) Cross-section and (b) schematic top-view of D-mode Al_2O_3/MBE-Gd_2O_3 (3MLs)/ InAs MOSFET.

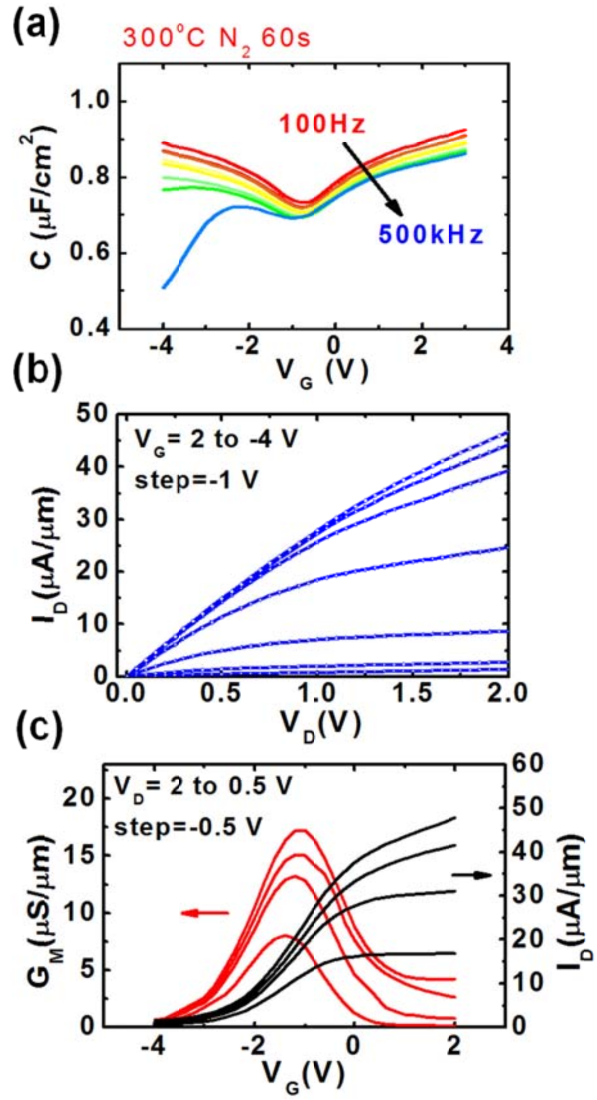

Fig. 3 (a) CV curve (b) Output characteristics I_D *vs* V_D *and* (c) transfer characteristics *of depletion-mode i*-InAs MOSFET with 12μm gate length.